Decolorization of a baker's yeast industry effluent by Fenton oxidation

A. Pala*, G. Erden

Dokuz Eylül University, Engineering Faculty, Department of Environmental Engineering, Kaynaklar Campus, 35160 Buca, İzmir, Turkey

Abstract

Baker's yeast industry is an important industry in Turkey. Molasses is used as a raw material, which is an end product of sugar industry. Baker's yeast industry effluents contain various pollutants and are generally characterized with high chemical oxygen demand (COD), TKN, dark color and non-biodegradable organic pollutants. The objective of this study was to investigate the decolorization and the removal of non-biodegradable organic pollutants measured as mainly DOC, $SUVA_{254}$, $SUVA_{280}$ and COD parameters. Fenton oxidation was applied to biologically pre-treated effluent of full-scale wastewater treatment plant. Jar test method was used to determine the best operating conditions. The 600 mg/L H_2O_2/600 mg/L Fe^{2+} dosage was quite enough to obtain a high color removal efficiency of 97%. However, the best Fe^{2+}/H_2O_2 dosage was 1200 mg/L Fe^{2+}/800 mg/L H_2O_2 at pH 4 and in reaction time of 20 min for mineralization of DOC and COD. For these conditions, the maximum color removal efficiency was obtained as 99%, maximum DOC and COD removal efficiencies were obtained as 90 and 88%, respectively. Also, $SUVA_{254}$ and $SUVA_{280}$ values decreased.
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Keywords: Baker's yeast industry wastewater; Decolorization; Fenton's oxidation; UV absorbencies; SUVA

1. Introduction

Biological treatment methods have been widely employed to eliminate organic compounds in the wastewaters. However, these methods may not be sufficient for the removal of color and non-biodegradable materials in the wastewaters. Thus, it can be necessary to use more effective processes, such as Fenton oxidation for the destruction of color and refractory organics to comply the discharge limits.

Molasses can be defined as the end product of sugar manufacture and is a solution of sugar, organic matter and inorganic material in water. It is used in commercial production of baker's yeast. Both beet and cane molasses are used in yeast fermentation. The aromatic nature of molasses is the result of phenolic compounds. Colored compounds contained in molasses are predominantly melanoidins (sugar–nitrogen complexes), caramel substances, polyphenol-iron compounds and to a lesser extent

plant pigments. The humic non-sugars (or polymerized forms of melanoidins) are claimed to be particularly relevant to the color of yeast produced. The color of sugar solutions varies with pH, with the darker colors occurring at the higher pH levels [1].

Altınbas et al. (2002) studied on the Fenton oxidation of pre-treated baker's yeast industry effluents. They reported that the chemical oxygen demand (COD) and color removal efficiencies were found about 86 and 92%, respectively, for 30 min reaction time for three different types of effluents [2].

Several researchers have reported strong correlations between the aromatic carbon content and $UV_{254–280}$ absorbance of dissolved organic materials [3–5]. Specific ultraviolet absorbance (SUVA: UV absorbance at a particular wavelength is normalized by dividing by the dissolved organic carbon concentration (DOC)) provides a quantitative measure of unsaturated bonds and/or aromaticity within dissolved organic material. Increases in SUVA generally reflect higher humification, aromaticity and hydrophobicity of dissolved organic material. Natural waters with high $SUVA_{254}$ values (e.g., >4 L/mg-cm) have been shown to have

* Corresponding author. Tel.: +90 232 4127121; fax: +90 232 4531143.
  E-mail addresses: aysegul.pala@deu.edu.tr (A. Pala),
erdengulcin@yahoo.com (G. Erden).

a relatively high content of hydrophobic, aromatic and high molecular weight dissolved organic material fractions, such as humic and fulvic acids [6,7]. Recently, Karanfil and Kitiş [8] reported that naturally occurring organic matter can be characterized by non-specific parameters SUVA by using the DOC and ultraviolet absorbance in the range of 254–280 nm ($UV_{254-280}$) [8]. Also, Balcıoğlu and Ötker (2002) detected absorbance of the pharmaceutical effluents at wavelength of maximum absorption of active substances and 254 nm wavelengths, UV_{254}, representing the aromatic content of wastewater [9].

The purpose of this study is to conduct experimental tests employing Fenton oxidation process to the biologically treated baker's yeast industry effluents in order to remove color and non-biodegradable organic pollutants measured as mainly DOC, $SUVA_{254}$, $SUVA_{280}$ and COD parameters. The samples were collected from an industry located around the İzmir city in Turkey in treating baker's yeast industry effluents as anaerobic treatment and following to aerobic treatment in a full-scale treatment plant. The objective of the study was also to examine the effects of operating variables on the removal of color, DOC, SUVA and COD. The results obtained from the present study could provide significant information for practical purposes.

2. Materials and methods

In the experimental studies, jar test method was applied to the biologically treated baker's yeast industry effluents to determine the best $FeSO_4$ and H_2O_2 dosages and the best pH and reaction time to achieve maximum color, DOC and COD removal efficiencies.

The Fenton oxidation reaction proceeds batchwise and can be generally described as follows: (a) adjusting the pH value with acid to approximately 3; (b) adding ferrous(II) salt; (c) adding hydrogen peroxide; (d) reaction (30 min at 20 °C) and neutralizing with caustic soda solution or milk of lime then separating the solids (in a settling basin or centrifuge), if necessary.

Experiments were conducted using of 50% H_2O_2 and 20% $FeSO_4 \cdot 7H_2O$ solutions. pH of baker's yeast industry effluents (7.28) was adjusted to 3 by using H_2SO_4 (95–98%). Then, different dosages of H_2O_2 and $FeSO_4 \cdot 7H_2O$ were added into the 500 mL samples. Mixing at 120 rpm for 30 min and settling for 15 min was applied to samples. Then, settled samples were placed into new beakers with a volume of 300 mL and pH was adjusted to 7.5 with a 20% lime solution. Mixing at pH 7.5 was carried out for 20 min at a speed of 30 rpm. After a settling period of 4 h, samples were kept in an oven at 50 °C for 30 min to remove the interference of residual H_2O_2 on the COD measurement. Also, simple permanganometric test was applied to check the presence of residual H_2O_2 [10].

The effect of different variables was studied by changing each in turn while keeping the other constant.

2.1. Analytical measurements

The materials used in the experiments were $FeSO_4 \cdot 7H_2O$ solution and lime slurry (Ca $(OH)_2$) of 20% and H_2O_2 solution of 50% were prepared daily. All experiments were carried out in a jar test apparatus using glass beakers. Mixing speed of the apparatus was adjustable between 0 and 250 rpm. pH measurement was carried out with a pH-meter, conductivity and salinity were measured with a conductivity-meter. The measured parameters of wastewater during the experiments were total and dissolved chemical oxygen demand (mg/L), dissolved organic carbon (mg/L), total suspended solids (TSS, mg/L), color as Pt–cobalt and pH. COD and TSS were measured according to procedures given in Standard Methods (1992) [11]. DOC was measured by a DOHRMANN™ DC-190 Model high-temperature TOC Analyser. Absorbance measurements were made using Pharmacia LKB-Novaspe II model spectrophotometer and Jenway 6105 UV–vis spectrophotometer for the wavelengths ranging between 330 and 690 nm and between 240 and 330 nm, respectively.

3. Results and discussion

Baker's yeast industry effluents contain various pollutants. The operational data obtained from the full-scale wastewater treatment plant are given in Tables 1 and 2. According to Tables 1 and 2, the total average COD removal efficiency is 96%, total average suspended solids (SS) removal efficiency is 97% and biological oxygen demand (BOD) removal efficiency is 99%. These high removal efficiencies indicated that the wastewater treatment plant is operated well as required. However, non-biodegradable organic matter measured as COD parameter is still present in the wastewater with an average value of 731 mg/L. Although the color parameter is not measured, it is always strength dark color in effluent wastewater. The sample used in this study was taken from the effluent of biologically pre-treated baker's yeast industry effluent. For the characterization of sample, pH, DOC, color, COD, SS, total solids (TS), total volatile solids (TVS), salinity, conductivity, turbidity, total-N, PO_4–P, NO_3–N and NH_4–N measurements were made. These results are presented in Table 3.

3.1. The effect of pH on Fenton oxidation

The effect of pH on removal of DOC, COD and color parameters was investigated by changing the pH value between 3 and 6 at the fixed concentrations of 600 mg/L H_2O_2 and 600 mg/L Fe^{2+} and in 20 min reaction time. The best pH value was found to be pH 4 for all main parameters. The maximum COD and DOC removal efficiencies were found to be 78% for both of the parameters at pH 4 (Fig. 1). The relationship between pH and color removal was also investigated and the reduction of color at this pH value was recorded as 60

Table 1
Anaerobic influent characteristics obtained from full-scale wastewater treatment plant operation studies

Anaerobic influent

Date	Flow (m^3/d)	pH	VFA (mg/L)	COD (mg/L)	BOD (mg/L)	VSS (mg/L)	Oil and grease (mg/L)
07.06.2004	810	5.92	4123	20147	15420	1750	10
14.06.2004	810	5.94	4041	20200	15400	1720	9
21.06.2004	810	5.94	4224	20200	15300	1700	9
19.07.2004	750	5.92	3664	21800	15300	1700	9
26.07.2004	750	5.96	3843	20750	15400	1700	10
02.08.2004	750	5.98	3754	20680	15400	1700	10
09.08.2004	810	6.02	3941	21800	15100	1700	10
16.08.2004	809	6.04	4123	20124	15100	1600	9
23.08.2004	810	6.02	3846	20600	15400	1600	10
30.08.2004	810	6.01	3972	20604	15300	1600	9
06.09.2004	810	6.08	4111	20600	15200	1600	9
13.09.2004	810	5.98	3664	20400	15150	1500	9
20.09.2004	810	5.98	3793	20400	15100	1500	9
27.09.2004	808	5.96	3634	20190	14910	1300	9
04.10.2004	808	6.01	3972	20198	14900	1350	9
11.10.2004	750	6.12	3752	20200	14900	1300	10
18.10.2004	750	6.08	3909	20158	14700	1200	10
25.12.2004	750	6.04	3793	20843	14780	1200	10
01.11.2004	810	6.00	3843	20480	15150	1500	10
08.11.2004	810	6.02	4194	20258	14700	1450	10
15.11.2004	658	5.99	4114	20196	14600	1430	9
22.11.2004	658	6.01	4041	20100	14120	1450	9
29.11.2004	810	6.04	4616	21647	14700	1470	10
06.12.2004	750	5.99	4060	21913	14700	1600	10
13.12.2004	810	6.01	3418	21918	14120	1700	10
20.12.2004	810	6.04	3655	22001	14700	1750	10
27.12.2004	810	6.00	3655	22122	14750	1650	10
Average	783	6	3917	20760	14974	1545	10
Maximum	810	6.12	4616	22122	15420	1750	10

Pt–Co with a corresponding color removal efficiency of 97%. The effect of pH on color removal is shown in Fig. 2. Altınbas et al. (2002) also reported that maximum COD removal was obtained at pH 4.

3.2. The effect of reaction time on Fenton's oxidation

Reaction times were changed between 5 and 30 min in order to determine the effect of reaction time on removal effi-ciencies. The experiments were carried out at pH 4, using the fixed concentrations of 600 mg/L Fe^{2+} and 600 mg/L H_2O_2. Although color was removed in 5 min, the best reaction time based on DOC and COD parameters was found to be 20 min. COD decreased to 144 mg/L with 78% removal efficiency (Fig. 3) and DOC decreased to 51 mg/L with 80% removal efficiency at 20 min reaction time (Fig. 3). Color reduced to 75 Pt–Co with a corresponding color removal efficiency of 96% (Fig. 4).
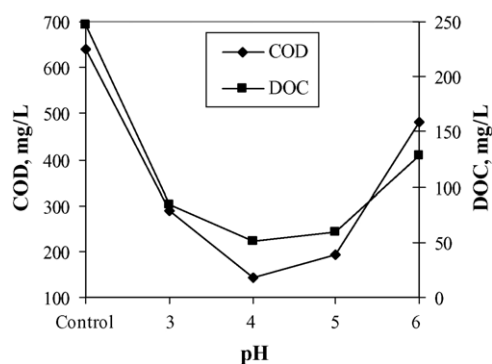

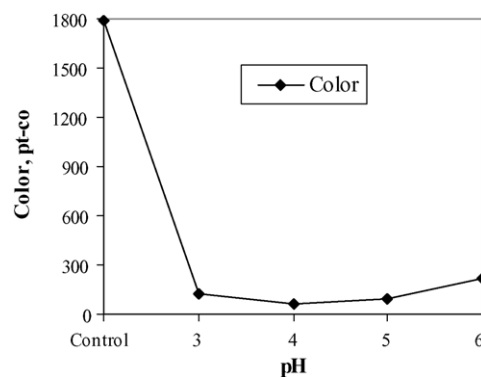Fig. 1. COD and DOC removals at different pH values.

Fig. 2. Color removals at different pH values.

Table 2
Aerobic influent and aerobic effluent characteristics obtained from full-scale wastewater treatment plant operation studies

Aerobic influent								Aerobic effluent						
Date	Flow (m³/d)	pH	VFA (mg/L)	COD (mg/L)	BOD (mg/L)	VSS (mg/L)	Oil and grease (mg/L)	Flow (m³/d)	pH	VFA (mg/L)	COD (mg/L)	BOD (mg/L)	VSS (mg/L)	Oil and grease (mg/L)
07.06.2004	315	7.76	195	4034	3004	600	10	1125	7.70	35	899	100	40	9
14.06.2004	315	7.72	214	4040	3000	600	9	1125	7.74	15	850	105	40	8
21.06.2004	315	7.74	208	4035	2890	600	9	1125	7.80	12	845	100	40	8
19.07.2004	300	7.76	101	3746	2880	400	9	1050	7.72	9	680	125	20	8
26.07.2004	300	7.74	94	4150	2786	500	9	1050	7.68	12	720	120	25	8
02.08.2004	300	7.78	101	4136	2780	500	9	1050	7.62	15	745	125	33	9
09.08.2004	315	7.79	82	4360	2800	500	9	1125	7.72	18	753	130	40	9
16.08.2004	318	7.74	69	4048	2800	500	9	1127	7.72	11	704	130	42	8
23.08.2004	314	7.76	72	4120	2920	600	9	1124	7.70	8	718	128	46	8
30.08.2004	314	7.78	88	4120	2900	600	9	1124	7.71	7	709	134	44	8
06.09.2004	314	7.74	94	4125	2850	600	9	1124	7.70	9	718	138	48	8
13.09.2004	316	7.71	82	4080	2870	600	9	1126	7.78	9	699	128	40	8
20.09.2004	316	7.69	80	4080	2800	600	9	1126	7.68	8	685	128	40	8
27.09.2004	314	7.71	77	4030	2758	600	9	1122	7.48	8	688	101	60	9
04.10.2004	314	7.74	70	4000	2700	600	9	1122	7.70	7	674	100	55	8
11.10.2004	297	7.79	68	4040	2650	600	8	1047	7.68	7	683	100	43	7
18.10.2004	297	7.76	77	4031	2630	600	8	1047	7.68	7	601	96	28	8
25.12.2004	297	7.72	72	4080	2250	600	9	1047	7.78	7	610	90	40	9
01.11.2004	313	7.69	70	4096	2411	600	9	1123	7.83	6	755	115	38	7
08.11.2004	313	7.72	68	4050	2620	600	9	1123	7.83	6	783	120	40	8
15.11.2004	255	7.78	66	4035	2620	550	9	913	7.00	6	685	120	28	8
22.11.2004	254	7.74	68	4028	2610	500	9	912	7.19	6	704	131	30	9
29.11.2004	315	7.74	60	4320	2900	550	9	1125	7.52	6	763	148	40	8
06.12.2004	308	7.73	62	4382	2850	550	9	1058	7.38	6	704	140	38	8
13.12.2004	315	7.68	64	4285	2600	600	9	1125	7.38	6	718	120	30	9
20.12.2004	313	7.70	60	4224	2630	600	9	1123	7.42	6	810	118	32	9
27.12.2004	313	7.73	62	4380	2620	550	9	1123	7.68	6	828	125	40	9
Average	306	8	90	4113	2746	567	9	1089	8	10	731	119	39	8
Maximum	318	7.79	214	4382	3004	600	10	1127	7.83	35	899	148	60	9

Table 3
Characteristics of wastewater used in Fenton oxidation experiments

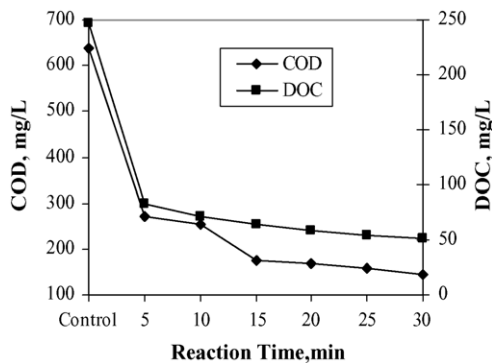| Parameter	Value
pH	7.28
DOC (mg/L)	247
COD (mg/L)	640
Soluble COD (mg/L)	480
SS (mg/L)	82
TSS (mg/L)	3040
TVS (mg/L)	732
Salinity (‰)	0.9
EC (μmhos/cm)	2300
Turbidity (JTU)	740
Total-N (mg/L)	110.4
Total-P (mg/L)	23.4
PO_4–P (mg/L)	7.5
NO_3–N (mg/L)	21
NH_4–N (mg/L)	25.5
Color (Pt–Co)	1790

Fig. 3. COD and DOC removals at different reaction times.

3.3. The effect of neutralization on Fenton's oxidation

The effects of neutralization on treatment efficiencies following Fenton's oxidation process were investigated. For this purpose, removal efficiencies were recorded at both pH 4 and 7.5 after oxidation period. Removal efficiency was slightly higher at pH 7.5 than at pH 4. Results of the experiment are depicted in Table 4.
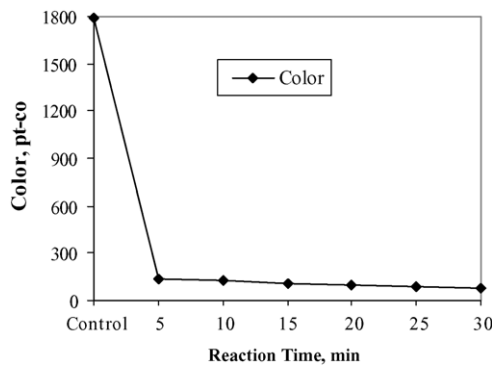

Fig. 4. Color removal at different reaction times.

Table 4
The effect of neutralization on COD, DOC and color removal for different H_2O_2/Fe^{2+} dosages

Dosages (mg/L)	COD removal efficiency (%), pH 4	COD removal efficiency (%), pH 7.5	DOC removal efficiency (%), pH 4	DOC removal efficiency (%), pH 7.5	Color removal efficiency (%), pH 4	Color removal efficiency (%), pH 7.5
200 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	48	51	51	60	77	82
400 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	60	65	64	72	92	94
600 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	80	83	74	84	95	97
800 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	82	85	81	89	96	98
1000 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	83	88	83	90	97	99
1200 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	78	80	82	89	93	96

Table 5
The results of series 1

| Dosages (mg/L)	Effluent COD (mg/L)	Effluent color (Pt–Co)	Effluent TOC (mg/L)	UV_{254}	$SUVA_{254}$	UV_{280}	$SUVA_{280}$
Control	640	1790	246.90	6.70	2.71	6.07	2.45
200 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	312	320	98.54	2.79	2.83	2.55	2.59
400 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	224	110	69.26	1.30	1.88	0.81	1.17
600 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	112	55	32.56	0.58	1.78	0.37	1.14
800 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	96	30	27.12	0.43	1.59	0.31	1.14
1000 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	80	15	24.17	0.40	1.65	0.26	1.08
1200 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	128	80	26.35	0.45	1.71	0.31	1.18
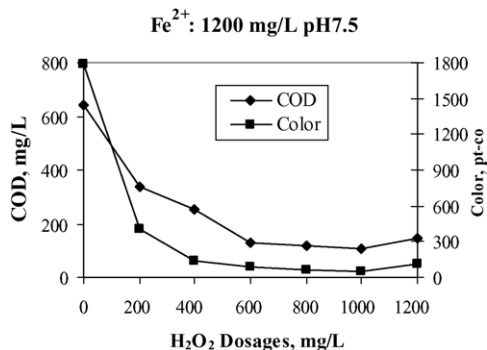
Fig. 5. The effect of H_2O_2 dosage on COD and color removal.
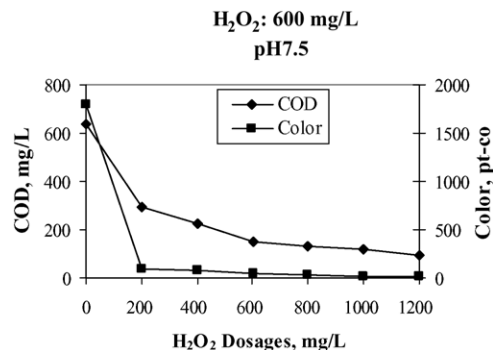

Fig. 6. The effect of Fe^{2+} dosage on COD and color removal.

3.4. The effect of Fenton's reagent dosages on Fenton oxidation

Experiments were carried out at different Fe^{2+} and H_2O_2 dosages at pH 4 and in 20 min reaction time to obtain the best dosages. Four series, each including six different dosages, were subjected to jar test experiments. In the first series, in order to investigate the effect of H_2O_2 concentration on color, COD and DOC removal, experiments were conducted at different H_2O_2 concentrations at a fixed Fe^{2+} concentration. Fe^{2+} dosage was kept constant at 1200 mg/L, while H_2O_2 dosage was altered from 200 to 1200 mg/L (Fig. 5). In this series, the best Fe^{2+} and H_2O_2 dosages based on removal efficiencies were determined to be 1000 mg/L H_2O_2 and 1200 mg/L Fe^{2+} (Table 5). Application of these dosages resulted with the removal efficiencies of 88, 99 and 90% for COD, DOC and color, respectively. $SUVA_{254}$ and $SUVA_{280}$

values decreased with increasing dosages of H_2O_2 for series 1.

In the second series, experiment was carried out at a fixed H_2O_2 dosage of 600 mg/L and different Fe^{2+} dosages increasing from 200 to 1200 mg/L (Fig. 6) in order to investigate Fe^{2+} concentration effect to Fenton oxidation. It was observed that removal efficiency increased with increasing dosage of Fe^{2+}. The results of series 2 are presented in Table 6. $SUVA_{254}$ and $SUVA_{280}$ values of each dosage of Fenton's reagent were found to be lower than control's $SUVA_{254–280}$ values in series 2. Studies have shown that during Fenton's oxidation, color removal of wastewater was faster than DOC and COD removal. UV scan of the treated solution showed a very sharp decrease indicated to mineralization effect.

In third series, jar test was carried out at a fixed dosage of $Fe^{2+} = 600$ mg/L and different H_2O_2 dosages increasing from 100 to 600 mg/L in order to investigate H_2O_2 cost effect. It

Table 6
The results of series 2

Dosages (mg/L)	Effluent COD (mg/L)	Effluent color (Pt–Co)	Effluent DOC (mg/L)	UV_{254}	$SUVA_{254}$	UV_{280}	$SUVA_{280}$
Control	640	1790	246.90	6.70	2.71	6.05	2.45
600 mg/L H_2O_2 + 200 mg/L Fe^{2+}	296	90	126.31	1.95	1.54	1.60	1.27
600 mg/L H_2O_2 + 400 mg/L Fe^{2+}	224	75	94.64	1.45	1.53	1.18.	1.25
600 mg/L H_2O_2 + 600 mg/L Fe^{2+}	152	50	60.28	0.90	1.49	0.73	1.21
600 mg/L H_2O_2 + 800 mg/L Fe^{2+}	132	35	51.57	0.75	1.45	0.60	1.16
600 mg/L H_2O_2 + 800 mg/L Fe^{2+}	116	20	45.12	0.60	1.33	0.48	1.06
600 mg/L H_2O_2 + 1200 mg/L Fe^{2+}	96	15	34.43	0.45	1.31	033	0.96

Table 7
The results of Fenton's series 3

Dosages (mg/L)	Effluent COD (mg/L)	Effluent color (Pt–Co)	Effluent DOC (mg/L)	UV_{254}	$SUVA_{254}$	UV_{280}	$SUVA_{280}$
Control	640	1790	246.9	6.70	2.71	6.05	2.45
100 mg/L H_2O_2 + 600 mg/L Fe^{2+}	264	285	102.31	1.81	1.77	1.37	1.34
200 mg/L H_2O_2 + 600 mg/L Fe^{2+}	232	115	93.53	1.50	1.60	1.20	1.28
300 mg/L H_2O_2 + 600 mg/L Fe^{2+}	200	105	87.15	1.35	1.55	0.97	1.11
400 mg/L H_2O_2 + 600 mg/L Fe^{2+}	184	90	81.42	1.16	1.42	0.86	1.06
500 mg/L H_2O_2 + 600 mg/L Fe^{2+}	168	80	75.13	1.01	1.34	0.75	1.00
600 mg/L H_2O_2 + 600 mg/L Fe^{2+}	152	60	63.41	0.83	1.31	0.62	0.98

Table 8
The results of Fenton's series 4

| Dosages (mg/L)	Effluent COD (mg/L)	Effluent color (Pt–Co)	Effluent DOC (mg/L)	UV_{254}	$SUVA_{254}$	UV_{280}	$SUVA_{280}$
Control	640	1790	246.90	6.70	2.71	6.05	2.45
100 mg/L H_2O_2 + 100 mg/L Fe^{2+}	426	930	136.59	2.35	1.72	1.84	1.35
200 mg/L H_2O_2 + 200 mg/L Fe^{2+}	330	440	125.15	1.98	1.58	1.57	1.25
300 mg/L H_2O_2 + 300 mg/L Fe^{2+}	300	210	98.35	1.51	1.54	1.16	1.18
400 mg/L H_2O_2 + 400 mg/L Fe^{2+}	234	120	80.61	1.16	1.44	0.86	1.07
500 mg/L H_2O_2 + 500 mg/L Fe^{2+}	220	105	71.37	1.01	1.42	0.72	1.00
600 mg/L H_2O_2 + 600 mg/L Fe^{2+}	170	80	60.51	0.82	1.36	0.59	0.98
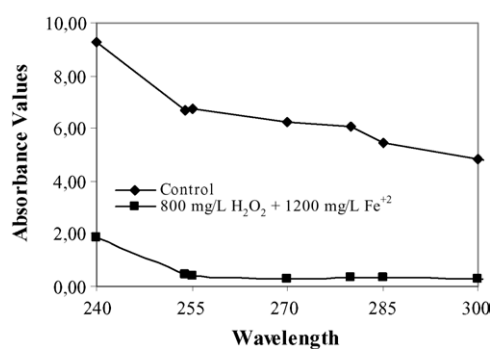
Fig. 7. The effect of Fenton's oxidation (1000 mg/L H_2O_2 + 1200 mg/L Fe^{2+}) on absorbance removal (240–315λ).

was observed that removal efficiency increased by increasing the H_2O_2 dosage. The results of series 3 are presented in Table 7. $SUVA_{254}$ and $SUVA_{280}$ values of each dosage of Fenton's reagent were found to be lower than control's $SUVA_{254-280}$ values.
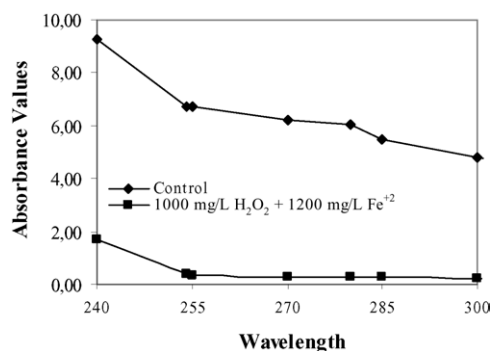

Fig. 8. The effect of Fenton's oxidation (800 mg/L H_2O_2 + 1200 mg/L Fe^{2+}) on absorbance removal (240–315λ).

In series 4, both H_2O_2 and Fe^{2+} dosages increased from 100 to 600 mg/L. It was observed that removal efficiencies increased with increasing dosages. Results of Fenton's series 4 are illustrated in Table 8. $SUVA_{254}$ and $SUVA_{280}$ values of each dosage of Fenton's reagent were found to be lower than control's $SUVA_{254-280}$ values. Altınbas et al. (2002) found that the dosages of H_2O_2 and Fe^{2+} are strongly dependent on the COD levels of the waste to be treated. Also, COD and color removals are significantly dependent on the initial COD levels. But this study showed that color removal is faster than COD removal and independent than COD removal.

The effect of Fenton's oxidation of 800 mg/L H_2O_2 + 1200 mg/L Fe^{2+} and of 1000 mg/L H_2O_2 + 1200 mg/L Fe^{2+} dosages on absorbance removal at 240–315λ are shown in Figs. 7 and 8. The results show that 800 mg/L H_2O_2 + 1200 mg/L Fe^{2+} concentrations are quite enough to oxidize the refractory COD in the wastewater.

4. Conclusion

Removal of color, DOC and COD increased with the increase of the H_2O_2 and Fe^{2+} concentrations. The 600 mg/L H_2O_2/600 mg/L Fe^{2+} dosage was quite enough to obtain a high color removal efficiency of 97%. However, the best Fe^{2+}/H_2O_2 dosage was 1200 mg/L Fe^{2+}/800 mg/L H_2O_2 at pH 4 and in reaction time of 20 min to obtain whole mineralization of DOC and COD. For these conditions, the maximum color removal efficiency was obtained as 99%, maximum DOC and COD removal efficiencies were obtained as 90 and 88%, respectively. $SUVA_{254}$ (1.65) and $SUVA_{280}$ (1.16) values were found to be under 3, which reveals that Fenton oxidation-treated wastewater contains relatively low content

of aromaticity, hydrophobicity of dissolved organic material and fulvic and humic acid. SUVA and absorbances data were supported to understand the Fenton's oxidation phenomena to remove the color, DOC and COD. As a result of this study, effluents follow to the Fenton oxidation process can comply with the discharge limits for color parameter when applied following the anaerobic-aerobic pretreatment.

References

[1] G.P. Meade, J.C.P. Chen, Cane Sugar Handbook, 10th ed., Wiley and Sons, NY, 1977.

[2] M. Altınbaş, A. Aydın, M. Sevimli, İ. Öztürk, Advanced oxidation of biologically pre-treated baker's yeast industry effluents for high recalcitrant COD and color removal, in: Fifth Specialised Conference on Small Water and Wastewater Treatment Systems, vol. 2, 2002, pp. 549–556.

[3] J.K. Edzwald, W.C. Becker, K.L. Wattier, Surrogate parameters for monitoring organic matter and THM precursors, J. AWWA 77 (4) (1985) 122–132.

[4] Y.P. Chin, G. Aiken, E. O'Loughlin, Molecular weight, polydispersity, and spectroscopic properties of aquatic humic substances, Environ. Sci. Technol. 28 (11) (1994) 1853–1858.

[5] T.K. Karanfil, J.E. Kilduff, M.A. Schlautman, W.J. Weber, Adsorption of organic macromolecules by granular activated carbon: 1 influence of molecular properties under anoxic solution conditions, Environ. Sci. Technol. 30 (7) (1996) 2187–2194.

[6] J.K. Edzwald, J.E. Van Benschoten, Aluminum coagulation of natural organic matter, in: H.H. Hahn, R. Klute (Eds.), Chemical Water and Wastewater Treatment, Springer-Verlag, Berlin, 1990.

[7] M.C. White, J.D. Thompson, G.W. Harrington, P.C. Singer, Evaluating criteria for enhanced coagulation compliance, J. AWWA 89 (5) (1997) 64–77.

[8] T. Karanfil, M. Kitiş, Formation and control of disinfection by-products during drinking water treatment operations, in: First National Environmental Pollution Symposium: Proceeding, Ankara, Turkey, 2000, pp. 17–26.

[9] I. Akmehmet Balcıoglu, M. Ötker, Oxidative treatment of antibiotics in pharmaceutical effluents, Fifth Specialised Conference on Small Water and Wastewater Treatment Systems, vol. 2, pp. 557–564.

[10] G. Erden, 2003. Advanced treatment of biologically pre-treated industry effluents, M.Sc. Thesis, Graduate School of Natural and Applied Sciences of Dokuz Eylul University (Supervisor: Aysegul Pala), Izmir, Turkey, September, 2003.

[11] American Public Health Association, American Water Works Association, Water Pollution Control Federation (1992) Standard Methods for the Examination of Waste and Wastewater, 18th ed., Washington, DC, USA.